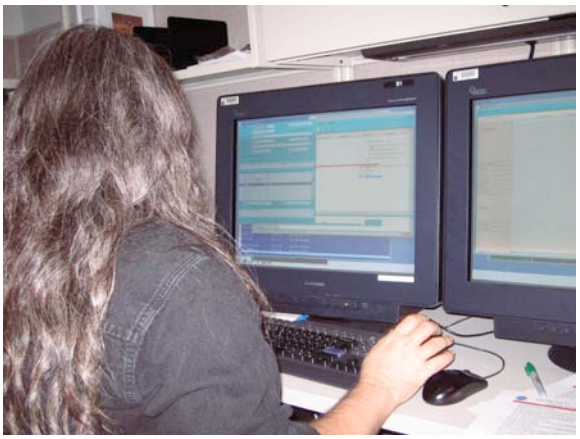
Mixed-Initiative Activity Planning

MAPGEN (Mixed Initiative Activity Plan Generator) is a ground-based decision-support system developed for the Mars Exploration Rover (MER) mission. This provides the operations team with an automatic planning and scheduling capability that significantly speeds up the daily planning process and increases the science return from the Martian surface. Such automated planning and scheduling systems have the potential of multiplying and magnifying future exploration missions by greatly reducing their cost and increasing their effectiveness.

Background

MAPGEN (Mixed-initiative Activity Plan GENerator), is an advanced multi-mission system for building and editing activity plans for spacecraft. It uses state of the art artificial intelligence techniques to assist the user in the generation of complex, robust, and safe plans. MAPGEN extends an existing mission planning system, called APGEN, by adding advanced planning and constraint reasoning techniques, resulting in a plan generation tool that offers revolutionary capabilities to its users. MAPGEN is currently being used twice daily, as a mission critical system in the uplink process to do the high-level planning for both rovers of the Mars Explorations Rovers (MER) mission on the surface of the Red Planet. When MAPGEN was used for the first time to command the Spirit rover on the 16th Martian day (or Sol) on January 18th, it became the first Artificial Intelligence based system to be used in operating a space platform on the surface of another planet.

An *activity plan* is a high-level description of activities that a spacecraft performs to fulfill its mission goals for some specific period of time. The plan may include engineering activities that are needed to maintain the health and safety of the spacecraft, as well as activities to generate data products for science. Such activity plans form the basis of sequences that are executed onboard the spacecraft. On MER, the tactical commanding process has been designed to command the two rovers every day, requiring that new activity plans be generated each day within a very narrow time window. This places a great burden on the Tactical Activity Planners, who are responsible for generating these daily activity plans. In order to enable these human planners to effectively perform their job under these circumstances, and to optimize the quantity and quality of science, the MER project chose MAPGEN as a mission-critical part of the mission operations software system.



Research Overview

MAPGEN and its use in the MER mission is a breakthrough in development and application of more intelligent and capable ground support tools for NASA missions. It has demonstrated that computing techniques can be combined with human knowledge and insight in a way that greatly benefits mission operations.

Mixed-Initiative Activity Planning

MAPGEN is one of a very small set of advanced AI tools that offer mixed-initiative interactive plan development to users. In a mixed-initiative system, the human user is in control, guiding and monitoring the progress of automated reasoning methods, and overriding them if necessary.

MAPGEN includes a number of notable advances in the field of mixed-initiative planning, in particular:
∑ Interactive constrained edits (constrained moves) – this technique allows users to modify the plans within the limits of the constraints and immediately see the overall impact of the changes made.
∑ Preferred temporal solution display for flexible plans – this new method for selecting single instantiations of flexible plans has proved to provide a very natural representation of the plan to the users, which has long been a difficult challenge
∑ Constraint-based mixed initiative planning with complex domain rules – the majority of previous mixed-initiative systems use simpler planning paradigms. MAPGEN is fully equipped with advanced flexible, quantitative constraint-based planning capabilities.

In terms of spacecraft operations technology, MAPGEN is a major leap forward in improving the capabilities of the tools used to operate spacecraft and other complex assets in space. Up to this point, most tools that have offered automation support for mission operations have done so only in terms of pre-defined algorithmic methods, such as scripts and macros. MAPGEN, on the other hand, automatically adapts the automation to the situation at hand. A prior tool called Plan-It-II, a forerunner of APGEN, allowed customized planning and scheduling support algorithms to be written in Lisp as part of the adaptation. This approach, with its burden of writing additional code, stands in contrast to MAPGEN, which uses a more easily adapted declarative model. In addition, the mixed-initiative nature of MAPGEN integrates the automated reasoning and planning capabilities seamlessly into the system's user interface.

Automatic plan generation and active constraint enforcement make it possible to explore many more options than ever before, thus yielding better plans that achieve more science in a more efficient manner. The active flight rule enforcement also increases safety by relieving the operator of having to check flight rules for complete plans.

The key advance of MAPGEN is that it enables operations staff to focus on the essential decisions that require human insight to make. This is due to conflict resolution and flight rule enforcement being done automatically while the human user is modifying the plan. Furthermore, the automation in MAPGEN is built on flexible computational techniques that can easily adapt to new and unforeseen situations. This significantly reduces the brittleness that has often plagued automated operations support tools.

Relevance to Exploration Systems

The research embodied in MAPGEN will be crucial for satisfying the needs of the Office of Exploration Systems. In order to explore the Moon and Mars without a substantial increase in the NASA budget, it will be essential to greatly reduce the cost of operations. A major proportion of this cost arises from staffing needed to plan and schedule activities for human and robotic explorers. This cost can be greatly reduced by the fruits of this research, while simultaneously increasing effectiveness.

H&RT Program Elements:

This research capability supports the following H&RT program /elements:

ASTP/Software, Intelligent Systems & Modeling

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